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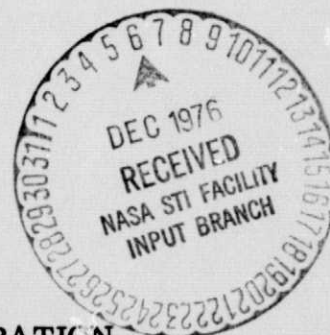


ASTP CHEMICAL AND MICROBIOLOGICAL
ANALYSIS OF POTABLE WATER

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ANALYSIS OF POTABLE WATER

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SUMMARY

The purpose of the Apollo-Soyuz Test Project chemical and microbiological analysis of potable water was to evaluate the adequacy of the Apollo command and service module water servicing and dispensing system. Following NASA specifications, sodium hypochlorite (NaOCl), a buffer (NaH_2PO_4), and an inhibitor (NaNO_3) were injected into the water system. Water samples were collected before and after flight and submitted to chemical and microbiological analyses. The preflight chemical analysis showed that the pH of the drink gun samples taken 24 hours before lift-off and of the final fill hot water port samples was somewhat lower than the specification limit. The postflight chemical analysis showed a nickel concentration calculated to be 1.68 mg/liter and specific conductivity and total residue exceeding specification limits. Microbiological analysis of preflight samples showed that bacterial growth in all samples except one was within specification limits. Microbiological analysis of all post-flight samples showed bacteria growth exceeding specification limits. No coliform, yeast, or mold organisms were found in preflight or postflight samples. All chemical and microbiological data indicated that the potable water was within acceptable limits, and the crew indicated that the water tasted reasonably good during the course of the mission.

INTRODUCTION

The purpose of the Apollo-Soyuz Test Project chemical and microbiological analysis of potable water was to evaluate the adequacy of the preflight and in-flight water servicing procedures including spacecraft water system sterilization/disinfection; the loading technique; the microbiological and chemical potability of the final load water; the command and service module (CSM) in-flight chlorination procedure; the potability of the water remaining in the CSM-111 potable water system after flight; the preflight and postflight nickel (Ni) concentration in the CSM-111 hot water dispensing system; and, using the data collected, the capability of the spacecraft system to deliver potable water.

DISCUSSION

Sample Collection and Analysis

Water samples were collected and analyzed according to the schedule and techniques described in reference 1. Preflight samples were collected by NASA John F. Kennedy Space Center (KSC) contractor personnel. The postflight samples were collected by NASA Lyndon B. Johnson Space Center (JSC) personnel.

Preflight and postflight samples were taken with a closed sampling system to preclude airborne microbial contamination, which could occur in sampling, by having a positive connection to the sample port and a closed, but vented, container to collect the samples. The sample containers were chemically clean and sterile aluminum, Teflon-anodized Apollo water sampling devices. (See ref. 2.) At each sample port, the samples for chemical analysis were taken before the samples for microbiological analysis.

The chemical and microbiological analyses were conducted by JSC and KSC contractor personnel.

Water Servicing

Preflight. - On June 23, 1975, at 6:00 a.m.¹, the ground-support equipment (GSE) was loaded with facility-deionized water meeting NASA specifications (ref. 1) for test point 2 (TP-2). (TP-2 is a point before the potable water load line/spacecraft load point interface.) At 5:00 a.m., the sodium hypochlorite (NaOCl), buffer (NaH_2PO_4), and inhibitor (NaNO_3) were added to the GSE water to achieve the following concentrations: chlorine, 11.3 mg/liter; buffer, 82.0 mg/liter; inhibitor, 52.0 mg/liter; and a pH of 6.7. At 6:00 p.m., the CSM-111 was loaded with GSE water for system sterilization. Sequential concentration determinations were made for the cold water port (CWP), hot water port (HWP), and drink gun (DG) during the ensuing time period. The results are shown in table I.

On July 11, 1975, at 10:00 a.m., the final fill of the CSM-111 water system was performed, and the lift-off (T) - 4 day samples were taken.

On July 14, 1975, at 2:00 a.m., the T - 24 hour samples were taken. At 6:00 p.m., the T - 9 hour chlorine-buffer-inhibitor injection was made into the CSM-111 water system using flight equipment. Two ampoules of NaOCl (1860 mg/liter) and one ampoule of NaH_2PO_4 (0.297 molar) plus NaNO_3 (0.217 molar) were used. At 8:00 p.m., the T - 9 hour chlorination concentrations were determined to be >20.0 p/m in the drink gun, 5.0 p/m in the CWP, and 2.5 p/m in the HWP.

¹All preflight time designations are local time at KSC.

In-flight.- The CSM-111 flight plan indicated that the schedule shown in table II would be used for in-flight chlorine injections. (No indication was given in crew debriefings that this schedule was not observed.)

RESULTS

Chemical Analysis

Preflight.- As shown in table III, all chemical parameters were within acceptable limits. It can be observed, however, that pH values for the final fill and T - 24 hour drink gun samples and for the final fill HWP sample were somewhat lower than the specification limit. (The specification permits a pH value of 6 to 8.) The pH values of the drink gun samples were 5.8 and 5.7, respectively, and the HWP sample had a pH of 5.9. Analysis of the data did not reveal a reason for the variances in pH.

Postflight.- As indicated in table IV, most chemical parameters were within the acceptable limits of NASA specifications for TP-3. (TP-3 is the onboard test/use port in the CSM.) A nickel concentration of 4.2 mg/liter was detected in the HWP. The effective nickel concentration was calculated (using $0.6 \times \text{Ni}$ concentration in CWP + $0.4 \times \text{Ni}$ concentration in HWP) to derive the value of 1.68 mg/liter. This value, according to previous decisions regarding exposure for a 10-day-duration mission, is acceptable. The chlorine residual in the CSM-111 CWP and HWP was checked after recovery. No measurable chlorine residual was detected. The specific conductivity and total residue concentration exceeded specification limits. These parameters, however, by themselves, do not constitute a health hazard.

Microbiological Analysis

Preflight.- As shown in table V, bacterial growth was found in all water samples except T - 9 hours. Total counts before lift-off ranged from 4 colonies/150 ml in the postchlorination TP-2 (on June 24, 1975) to 1.6×10^7 colonies/150 ml in the HWP sample at T - 24 hours. All samples except the HWP sample at T - 24 hours met the specification limit of 10^6 colonies/150 ml. The bacterial species was identified in all samples as Pseudomonas aeruginosa. No coliform, anaerobic, yeast, or mold organisms were found.

Postflight.- The postflight data in table VI show that an unidentified species of Flavobacterium was found in all samples. Total colonies count ranged from 7.35×10^6 colonies/150 ml in the HWP (10:50 p.m.) to 2.4×10^8 colonies/ml in the wastewater (11:50 p.m.). No coliform, yeast, or mold organisms were found. (Time designations for postflight samples are local time at Honolulu, Hawaii.)

CONCLUDING REMARKS

Water Quality

All chemical and microbiological data indicated that the potable water was within acceptable limits. The pH parameters varied slightly from the NASA specification limitation, but the variances were not considered significant. Specifically, the pH for three of the four TP-3 samples was 5.8, 5.7, and 5.9, respectively. The specification lower limit is 6.0. It is significant that bacteria were found in all samples taken after flight. The number of unused chlorine and buffer ampoules found onboard after flight and the lack of residual chlorine found in postflight samples indicate that four in-flight chlorinations were not performed; this could explain the high postflight bacteria level.

Crew Comments

The crew commented during the postflight debriefing session that the potable water tasted reasonably good during the course of the mission and that no chlorine taste was noted.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, October 7, 1976
199-73-01-05-72

REFERENCES

1. Command Service Module/Lunar Module/Orbital Workshop Potable Water Specification and Test Procedures. NASA Manned Spacecraft Center (now Lyndon B. Johnson Space Center) PF SPEC 1D, July 1971.
2. Sauer, Richard L.; and Calley, David J.: Potable Water Supply. Biomedical Results of Apollo. NASA SP-368, 1975, pp. 495-515.

TABLE I.- PREFLIGHT CHEMICAL CONCENTRATIONS

Time	Chlorine, mg/liter			Inhibitor, mg/liter			Buffer, mg/liter	
	HWP	CWP	DG	HWP	CWP	DG	HWP	CWP
June 24, 1975								
1:45 a.m.	--	--	--	--	--	--	--	97.7
2:00 a.m.	--	--	--	--	--	--	107.1	--
12:00 m.	7.9	6.8	8.4	60.0	60.0	60.0	--	--
6:00 p.m.	6.0	4.4	4.4	59.0	58.0	58.0	--	--
12:00 p.m.	3.2	2.8	2.8	55.0	56.5	57.0	--	--
June 25, 1975								
6:00 a.m.	1.6	2.4	2.8	54.0	54.5	56.0	--	--

TABLE II.- FLIGHT PLAN CHLORINATION SCHEDULE

Sequence	Ground-elapsed time, hr:min	Interval between additions, hr:min
1	15:15	--
2	36:15	21:00
3	58:25	22:10
4	83:15	24:50
5	108:45	25:30
6	134:00	25:15
7	159:15	25:15
8	183:15	24:00
9	^a 207:15	24:00

^aSplashdown.

TABLE III.- PESTICIDE CHEMICAL ANALYSIS

Properties	Limitation per MCA specification (see ref. 1)	Results of analysis from -							
		Ground-support equipment (TP-2)				Bot water port (TP-3)			
		Prechlorination ^a June 23 ^b 6:00 a.m. c	Postchlorination ^a June 24 5:00 p.m.	Postchlorination ^d June 26 10:00 a.m.	June 25 ^d 11:00 a.m.	T - 4 days ^d July 11 10:00 a.m.	T - 24 hours ^d July 14 2:00 a.m.	T - 4 days ^d July 11 10:00 a.m.	T - 24 hours ^d July 14 2:00 a.m.
pH, units	6 to 8	6.9	7.0	5.4	5.6	5.9	6.1	5.8	5.7
Conductivity, umhos/cm at 25°C	1.0	0.65	0.8	1.8	1.1	1.2	1.2	1.2	1.2
Total residue, mg/liter	2.0	0.73	0.9	9.0	13.0	12.0	12.0	12.0	12.0
Fixed residue, mg/liter	0.5	0.28	0.4	(e)	(e)	(e)	(e)	(e)	(e)
Taste and odor, threshold	3.0	13.0	13.0	3.0	3.0	13.0	13.0	13.0	13.0
Turbidity (nepeloid), units	11.0	11.0	11.0	10.0	10.0	10.0	10.0	10.0	10.0
Color, true	5.0	15.0	15.0	5.0	5.0	5.0	5.0	5.0	5.0
Toxic species:									
Aluminum, mg/liter	(f)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium, mg/liter	0.01	<0.01	<0.01	<0.01	<0.005	<0.005	0.008	<0.005	<0.005
Calcium, mg/liter	(f)	(e)	(e)	1.0	1.0	1.0	1.0	1.0	1.0
Chloride, mg/liter	(f)	<0.3	<0.3	0.5	0.5	0.5	0.75	1.0	1.0
Chromium (total), mg/liter	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper, mg/liter	1.0	1.0	1.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron, mg/liter	0.3	<0.3	<0.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lime, mg/liter	0.05	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Magnesium, mg/liter	(f)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese, mg/liter	0.05	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury, mg/liter	0.005	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel, mg/liter	0.05	<0.05	<0.05	0.1	0.38	0.75	0.12	<0.1	<0.1
Potassium, mg/liter	(f)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium, mg/liter	(f)	<0.01	<0.01	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Silicon, mg/liter	(f)	<0.5	<0.5	(e)	(e)	(e)	(e)	(e)	(e)
Sulfur, mg/liter	0.5	<0.5	<0.5	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Silver, mg/liter	0.05	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total nitrogen, mg/liter	10.0	<10.0	<10.0	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1

Analysis performed at EEC.

Values are all 1975.

Special time at EEC.

Analysis performed at JEC.

No analysis performed.

Reference only.

POOR QUALITY

TABLE IV.- POSTFLIGHT CHEMICAL ANALYSIS

[July 24, 1975]

Properties	Results of analysis from -		
	Drink gun 11:06 p.m. ^a	Hot water port 10:40 p.m.	Wastewater tank 11:47 p.m.
pH, units	6.9	7.3	6.6
Conductivity, umhos/cm at 298 K	144.0	154.0	29.9
Total residue, mg/liter	188.0	178.0	12.0
Fixed residue, mg/liter	(b)	(b)	(b)
Taste and odor, threshold	(b)	(b)	(b)
Turbidity (nephelos), units	<10.0	<10.0	10.0
Color, true	<1.0	<1.0	<1.0
Ionic species:			
Aluminum, mg/liter	<0.05	<0.05	<0.05
Cadmium, mg/liter	<0.005	<0.005	<0.005
Calcium, mg/liter	<1.0	<1.0	<1.0
Chromium (total), mg/liter	<0.05	<0.05	<0.05
Copper, mg/liter	<0.03	0.04	<0.03
Iron, mg/liter	<0.03	<0.03	<0.03
Lead, mg/liter	<0.05	<0.05	<0.05
Magnesium, mg/liter	<0.05	<0.05	<0.05
Manganese, mg/liter	<0.01	<0.01	0.01
Mercury, mg/liter	<0.0005	<0.0005	<0.0005
Nickel, mg/liter	0.07	4.2	1.1
Potassium, mg/liter	0.04	<0.005	<0.005
Selenium, mg/liter	<0.01	<0.01	<0.01
Silicon, mg/liter	(b)	(b)	(b)
Silver, mg/liter	<0.03	<0.03	<0.03
Sodium, mg/liter	(b)	(b)	(b)
Zinc, mg/liter	0.08	<0.005	0.25
Chloride, mg/liter	10.0	9.0	0.5
Total nitrogen, mg/liter	<10.0	<10.0	<10.0

^aLocal time at Honolulu, Hawaii.^bNo analysis performed.

TABLE V.- PREFLIGHT MICROBIOLOGICAL ANALYSIS^a

Date	Time ^b	Collection point	Organism	Total organism count, colonies/150 ml
June 23, 1975	6:00 a.m.	GSE (TP-2) prechlorination	<u>Pseudomonas aeruginosa</u>	32
June 24, 1975	5:00 p.m.	GSE (TP-2) postchlorination	<u>Pseudomonas aeruginosa</u>	4
June 26, 1975	10:00 a.m.	GSE (TP-2)	<u>Pseudomonas aeruginosa</u>	19
June 29, 1975	11:00 a.m.	CSM-111 (TP-3) initial fill		
		Drink gun	<u>Pseudomonas aeruginosa</u>	1×10^6
		Hot water port	<u>Pseudomonas aeruginosa</u>	1×10^6
July 11, 1975	10:00 a.m.	CSM-111 (TP-3) final fill		
		Drink gun	<u>Pseudomonas aeruginosa</u>	6×10^6
		Hot water port	<u>Pseudomonas aeruginosa</u>	16×10^6
July 14, 1975	2:00 a.m.	CSM-111 (TP-3) T - 24 hours		
		Drink gun	<u>Pseudomonas aeruginosa</u>	3×10^6
		Hot water port	<u>Pseudomonas aeruginosa</u>	1.6×10^7
July 14, 1975	10:00 p.m.	CSM-111 (TP-3) T - 9 hours postchlorination		
		Drink gun	Negative	
		Hot water port	Negative	

^aNo coliform, anaerobic, yeast, or mold organisms were found.^bTime designations are local time KSC.

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TABLE VI.- POSTFLIGHT MICROBIOLOGICAL ANALYSIS^a

[July 24, 1975]

Points of collection	Time ^b	Organism	Total organism growth, colony forming units/cm ³
Drink gun	11:20 p.m.	<u>Flavobacterium</u>	8.0×10^4
Hot water port	10:50 p.m.	<u>Flavobacterium</u>	4.9×10^4
Wastewater	11:53 p.m.	<u>Flavobacterium</u>	6.7×10^5

^aNo coliform, anaerobic, yeast, or mold organisms were found.

^bLocal time at Honolulu, Hawaii.